A Numerical Study of the Hot Gas Environment Around a STOVL Aircraft in Ground Proximity

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ABSTRACT

The development of Short Take-off Vertical Landing (STOVL) aircraft has been based on empiricism. In this study, a 3-D flow code was used to calculate the hot gas environment around a STOVL aircraft in ground proximity. Preliminary calculations are reported to identify key features of the flowfield, and to demonstrate the capability of a CFD code to calculate the temperature of the gases ingested at the engine inlet for typical flow and geometric conditions.

CALCULATIONS WERE DONE WITH A 3-D TEACH-TYPE CODE TO SOLVE THE TIME-AVERAGED NAVIER-STOKES EQUATIONS

EQUATIONS ARE SOLVED SEQUENTIALLY

A PRESSURE CORRECTION EQUATION IS SOLVED USING THE SIMPLE ALGORITM OF PATANKAR

HYBRID DIFFERENCING WAS USED TO SAVE MEMORY

A TWO EQUATION TURBULENCE MODEL WAS USED

CODE WAS USED FOR COMBUSTORS AND DID NOT INCLUDE A DENSITY CORRECTION TERM FOR RAPIDLY VARYING PRESSURE

EXIT BOUNDARY CONDITIONS WERE CHANGED FOR MODELING THE HOT GAS INGESTION PROBLEM

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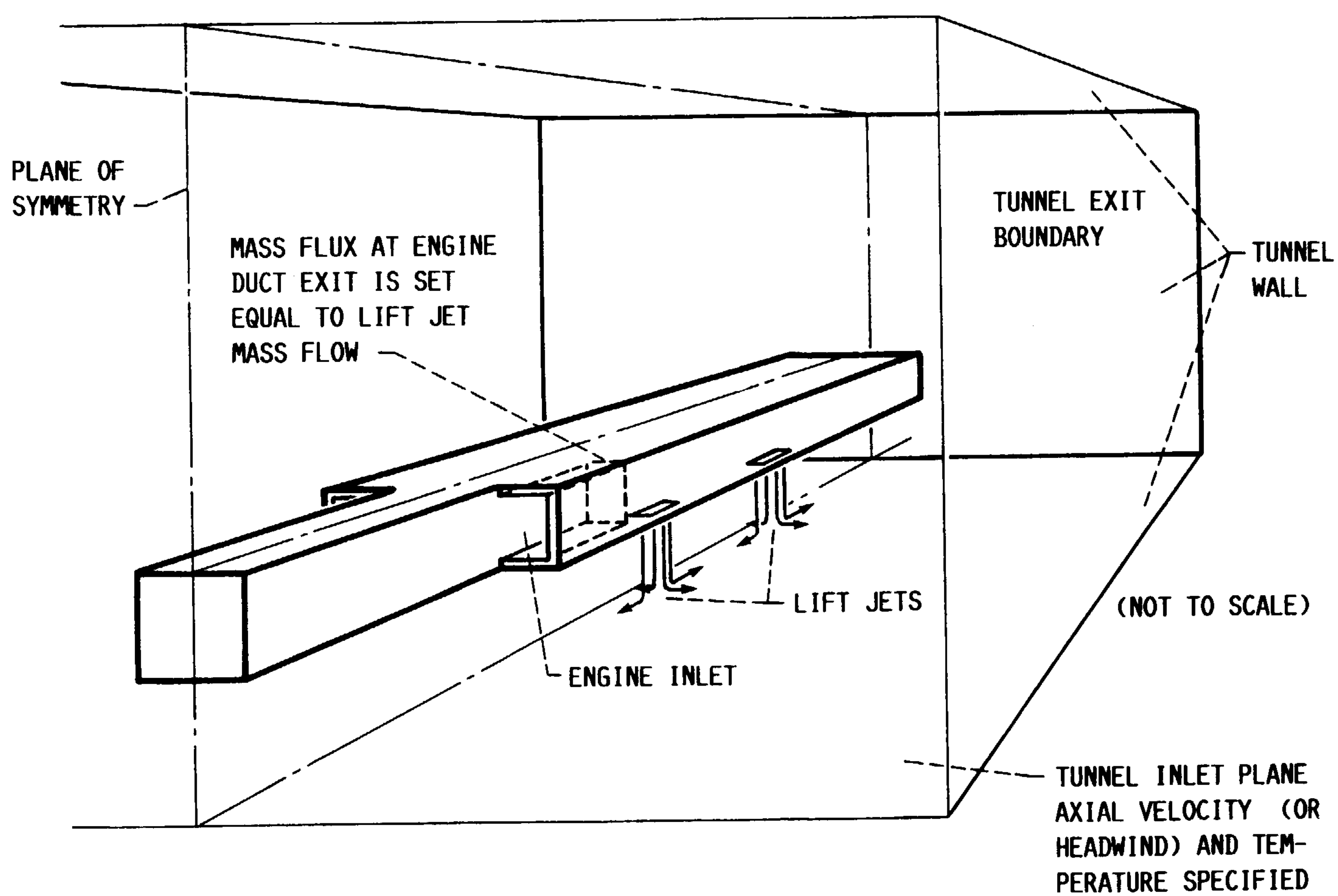
SCHEMATIC OF COMPUTATIONAL DOMAIN



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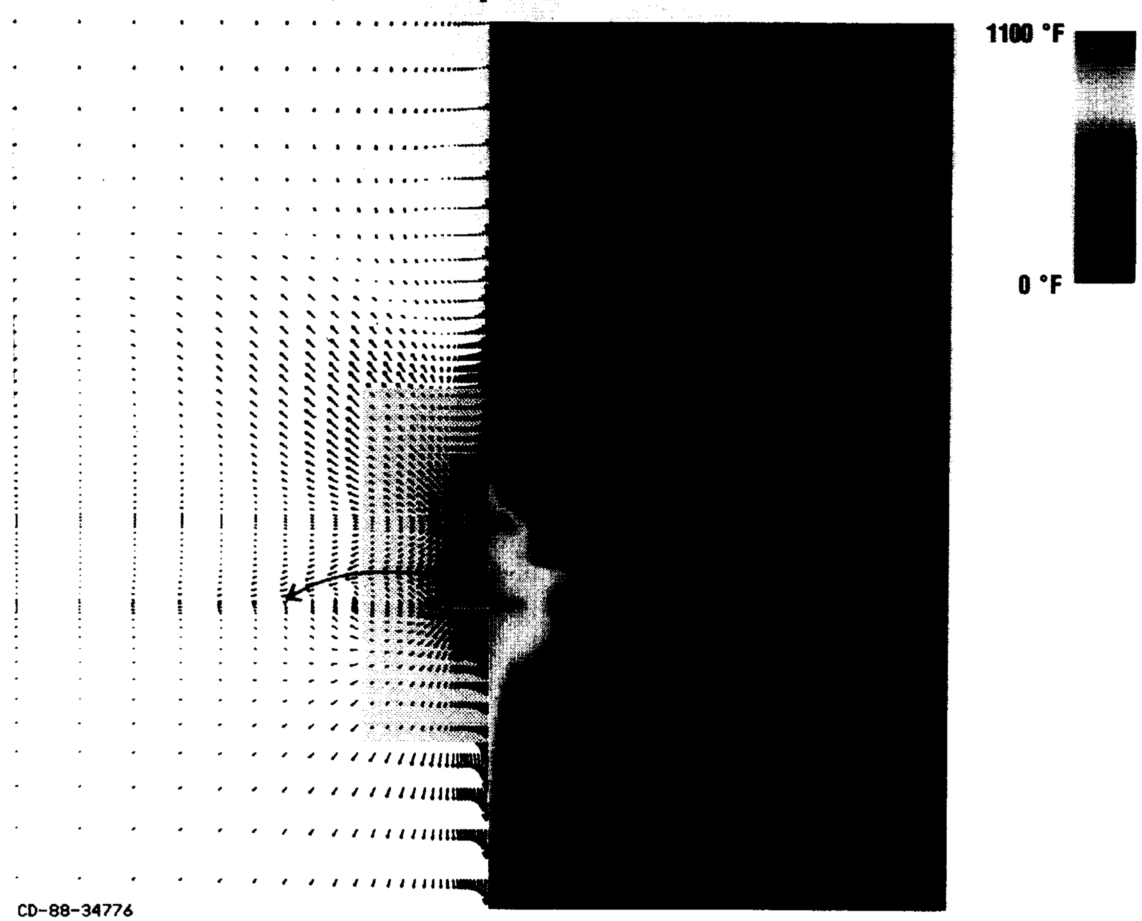
NEAR-GROUND PLANE VELOCITY AND TEMPERATURE DISTRIBUTIONS

(H/Dj=4)

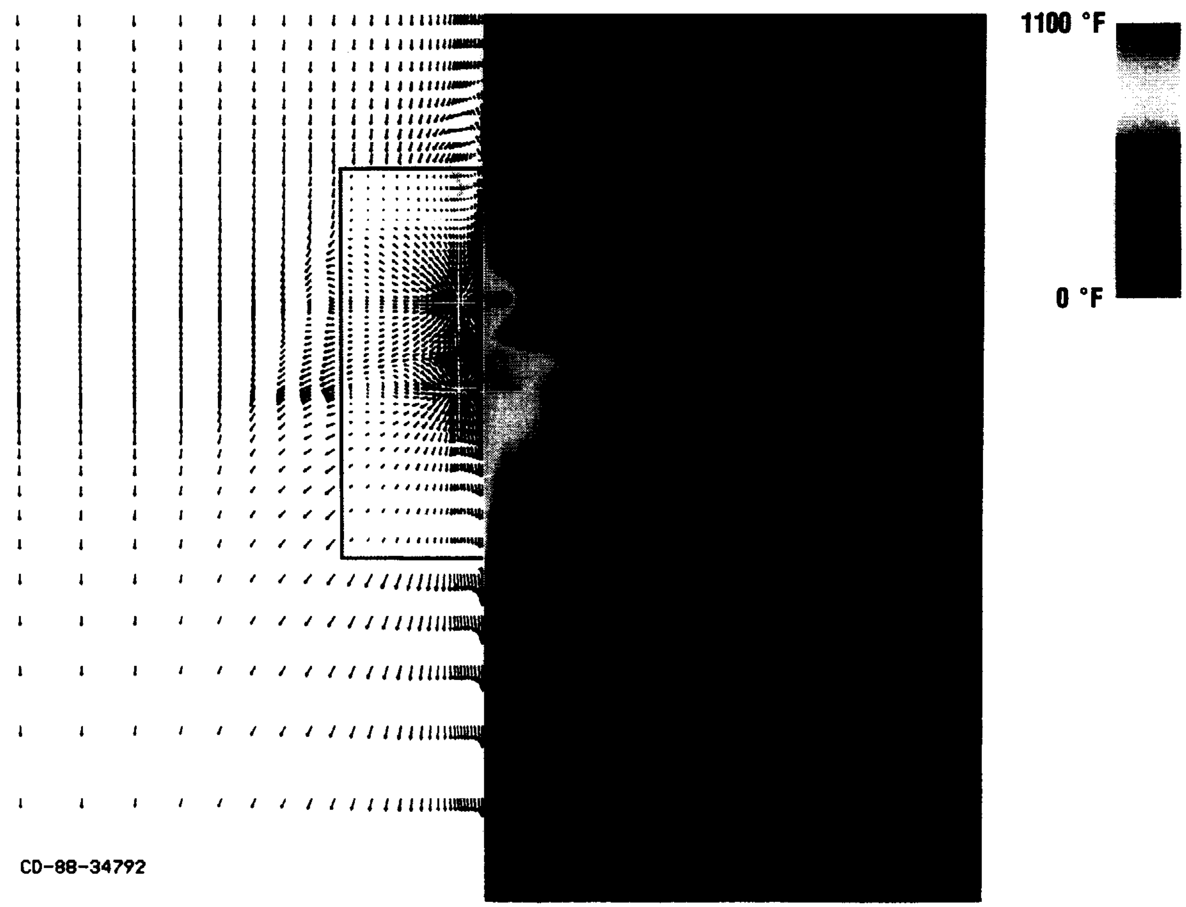
$U_\infty/V_j = 0.03$



NEAR-GROUND PLANE VELOCITY AND TEMPERATURE DISTRIBUTIONS

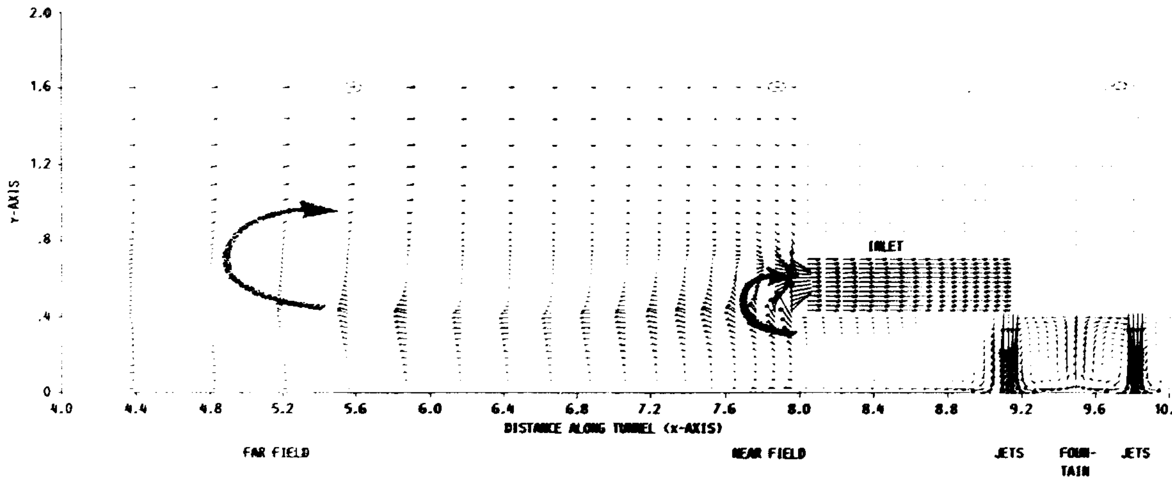
(H/Dj=4)

U∞/Vj=0.09



CALCULATED VELOCITY AND TEMPERATURE DISTRIBUTIONS IN VERTICAL X-Y PLANE THROUGH ENGINE INLET

($H/D_j = 4$; $U_\infty / V_j = 0.03$)



A) VELOCITY

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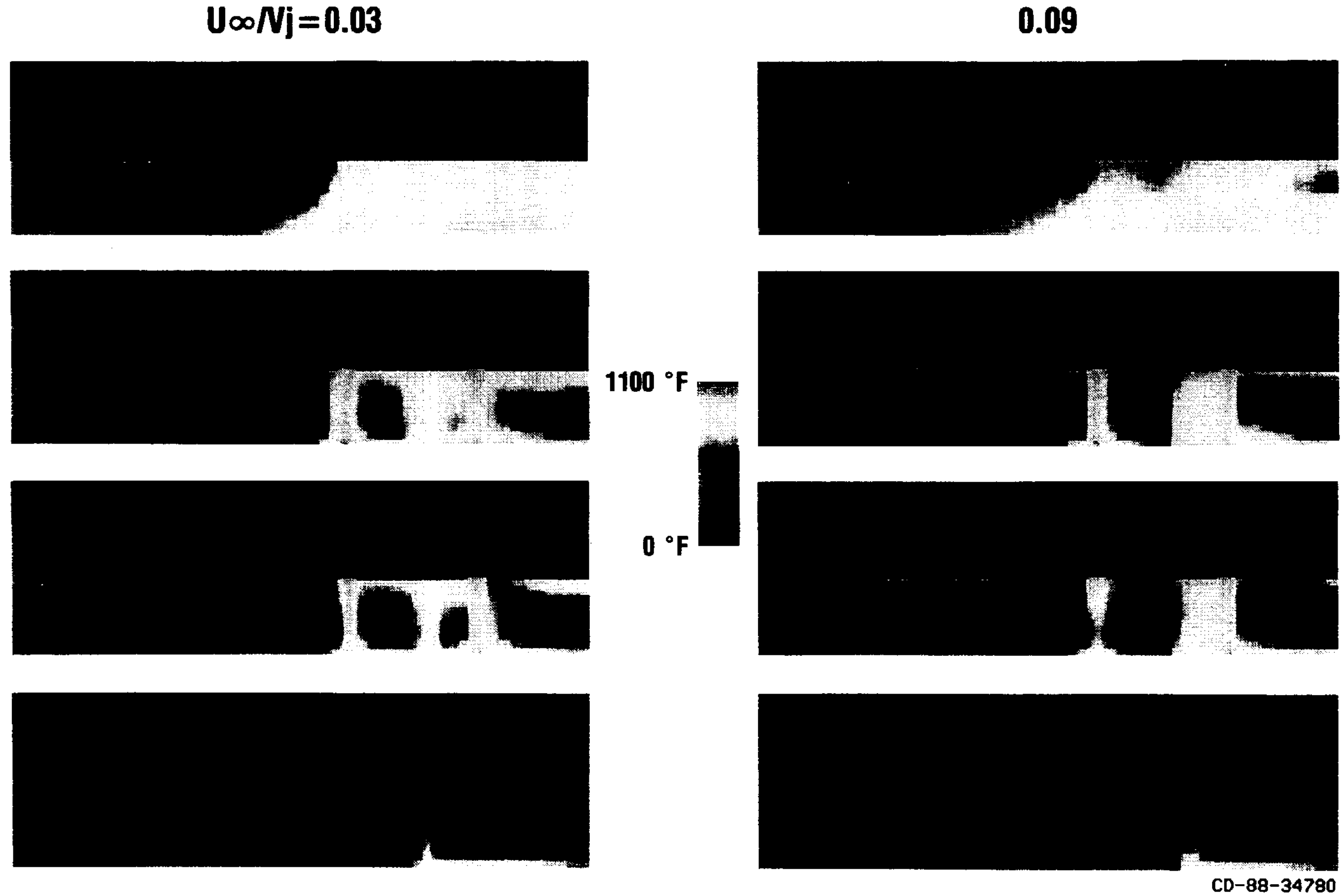
B) TEMPERATURE

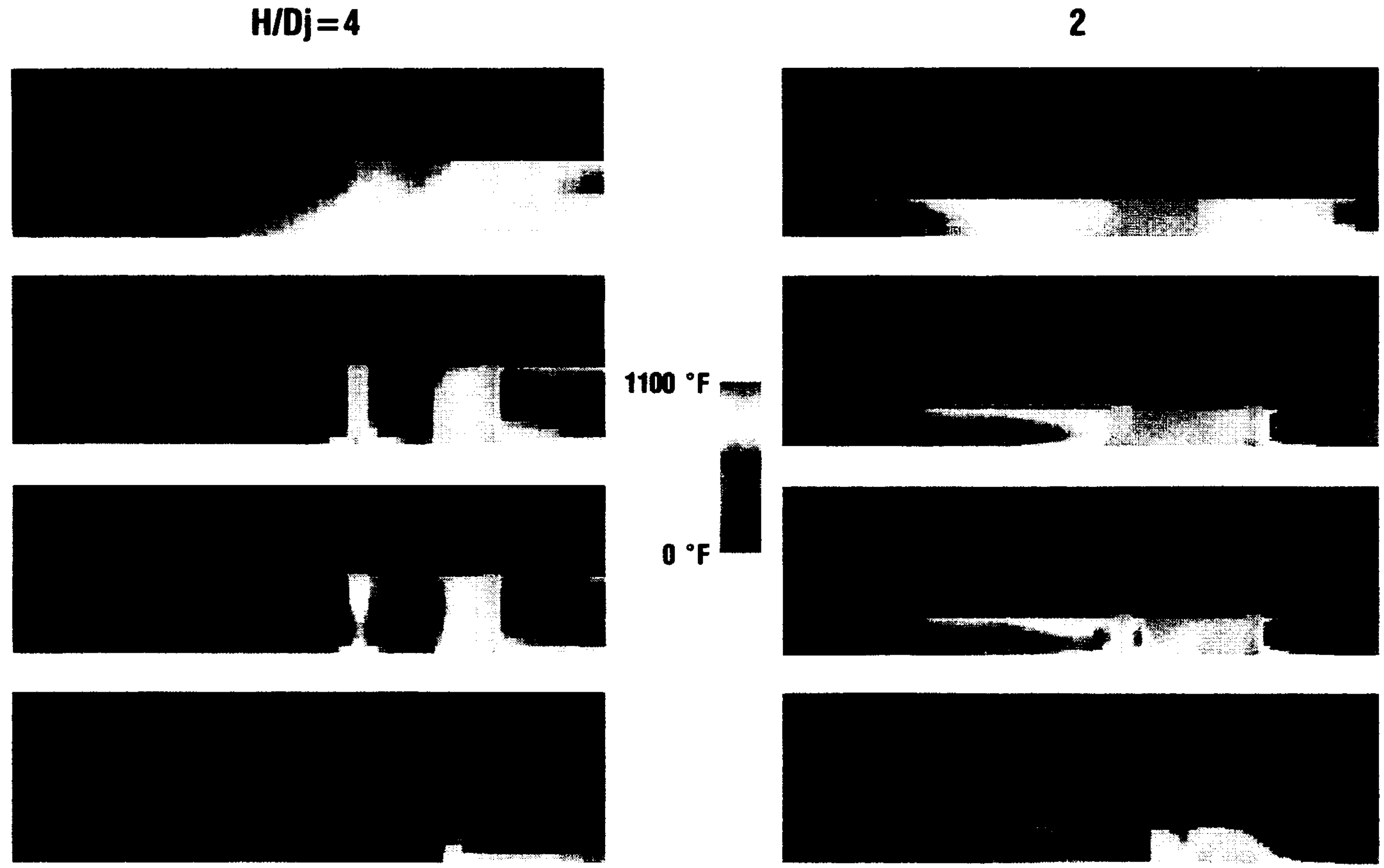
TEMPERATURE DISTRIBUTIONS IN VERTICAL PLANES FROM AIRCRAFT CENTERPLANE TO OUTBOARD OF FUSELAGE

(H/Dj=4)



TEMPERATURE DISTRIBUTIONS IN VERTICAL PLANES FROM AIRCRAFT CENTERPLANE TO OUTBOARD OF FUSELAGE

$(U_\infty/V_j = 0.09)$



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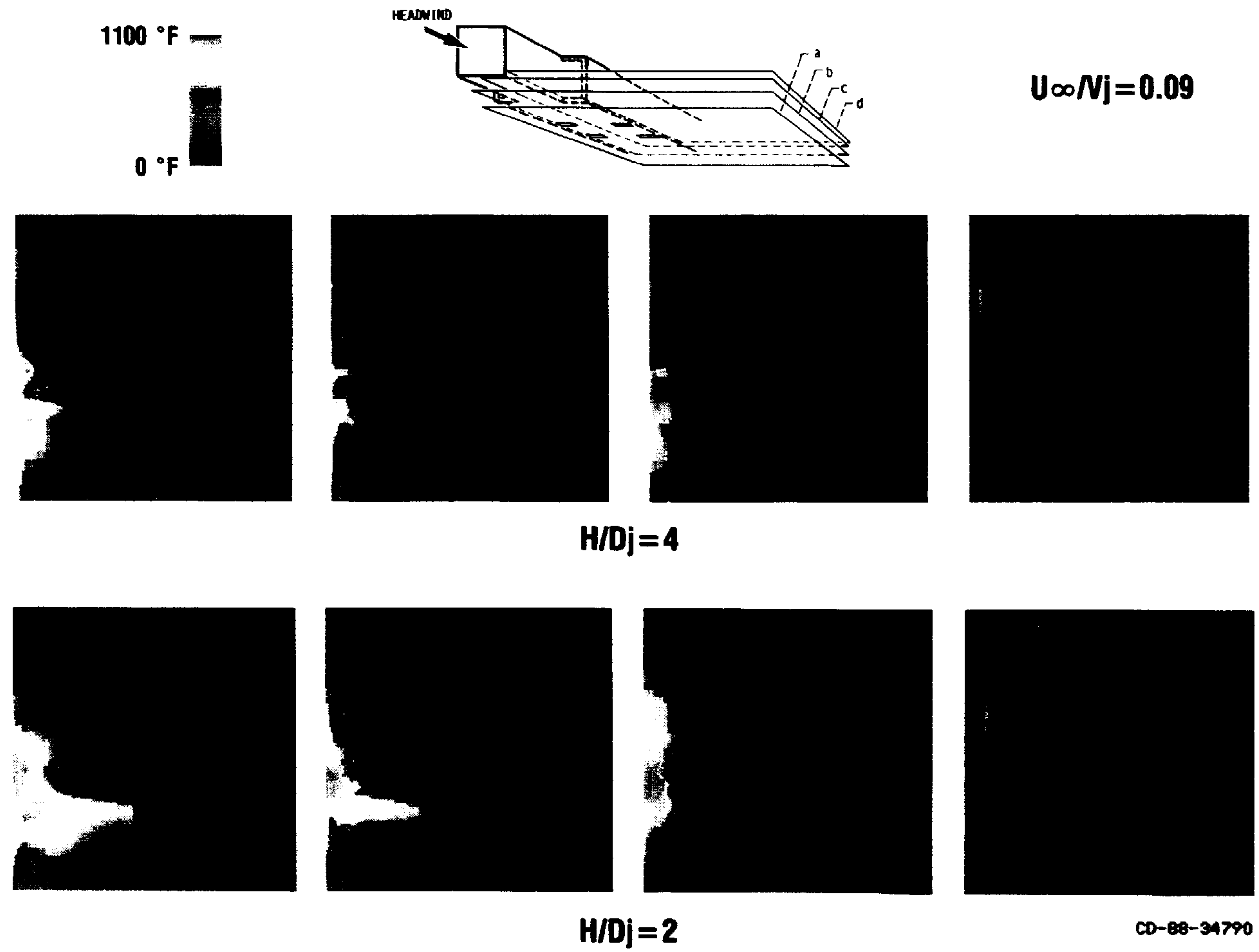
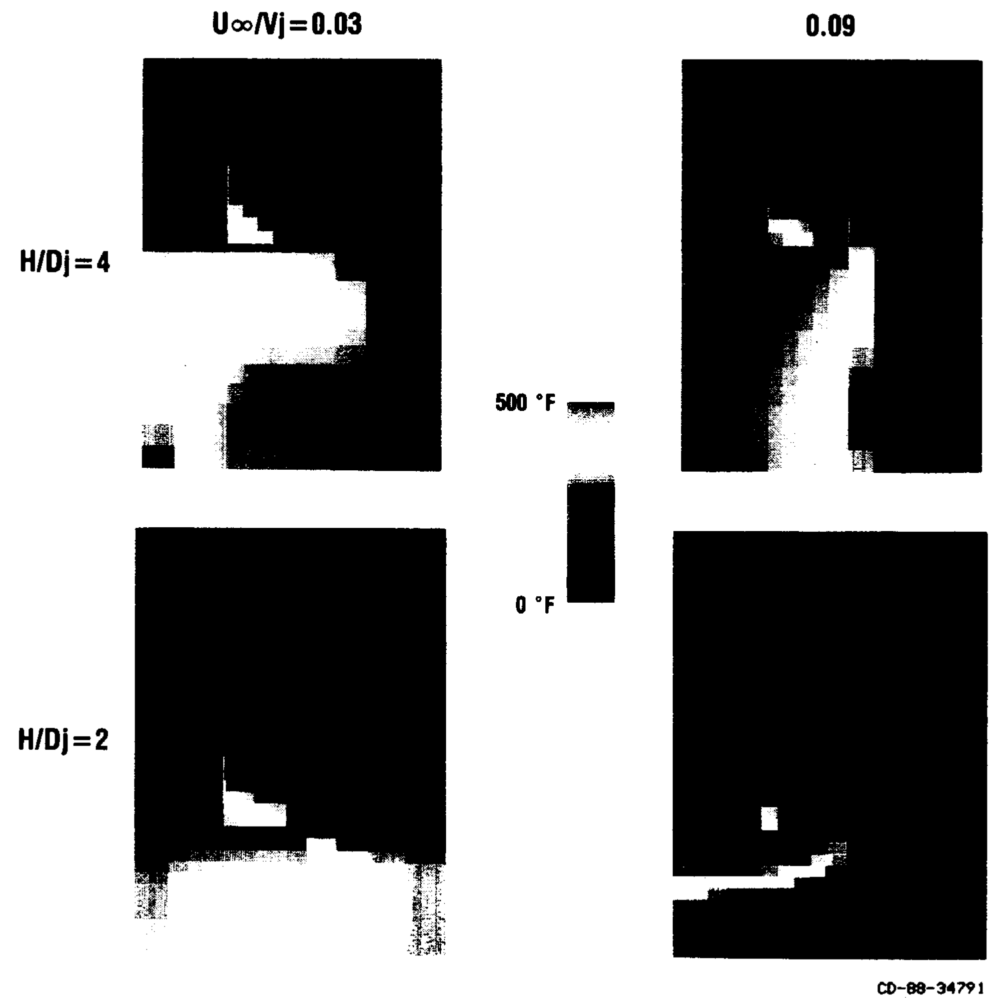
TEMPERATURE DISTRIBUTION IN HORIZONTAL PLANES
EFFECT OF CHANGING HEIGHT



TEMPERATURE DISTRIBUTIONS IN VERTICAL (Y-Z) PLANES THROUGH ENGINE INLET



Jet, Ambient, and Inlet
Temperatures for Cases Calculated[a]

U_∞ / V_j	H/D_j	U_∞, kn	T_{avg}	T_{max}	T_{min}
0.03	4	17.8	187.7	388.2	109.8
.03	2	17.8	173.5	429.6	72.0
.09	4	53.6	145.1	469.9	61.6
.09	2	53.6	97.6	375.3	62.3

[a]At nozzle pressure ratio of 1.21; $T_j = 1000$; $T_\infty = 70$ (all temperatures are degrees F).

Average Inlet Temperatures[a]

Distance from exhaust lift jets to ground plane, H/D_j	Ratio of forward speed of aircraft (or strength of headwind) to exhaust jet velocity, U_∞ / V_j	
	0.03	0.09
4	0.13	0.08
2	.11	.03

[a]$(T_{avg} - T_\infty)/(T_j - T_\infty)$

Inlet Temperature Distortion[a]

Distance from exhaust lift jets to ground plane, H/D_j	Ratio of forward speed of aircraft (or strength of headwind) to exhaust jet velocity, U_∞ / V_j	
	0.03	0.09
4	0.30	0.44
2	.38	.34

[a]$(T_{max} - T_{min})/(T_j - T_\infty)$

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SUMMARY

INTERNAL FLOW CODE CAN BE USED IN PREDICTING STOVL FLOWFIELDS

SIGNIFICANT INGESTION WAS PREDICTED IN ALL CASES CALCULATED

ALL CASES PREDICTED NEAR FIELD INGESTION

WEAKER HEADWINDS ALSO PREDICTED INGESTION BY GROUND VORTEX FLOW